Thermal Control of Electronics: Perspectives and Prospects

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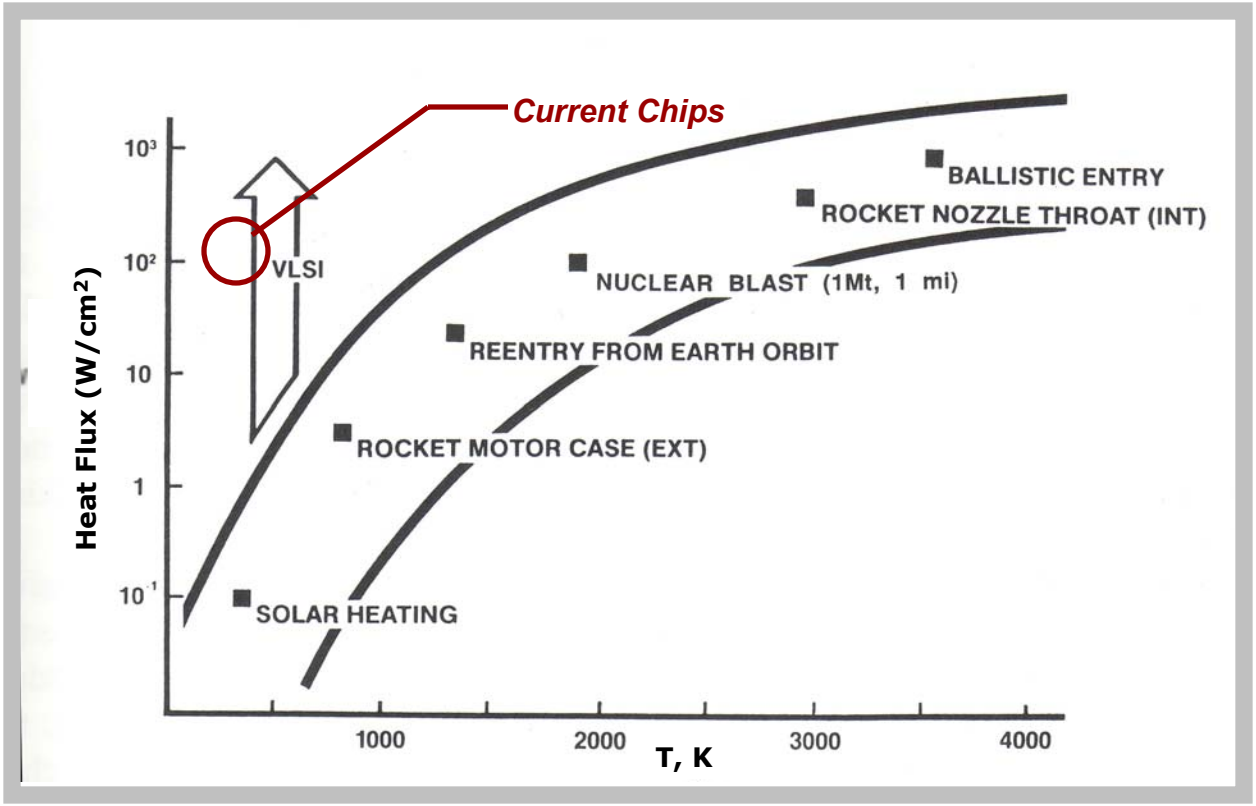
Introduction

- Thermal control of electronics is posing significant challenges (again)
- New, or re-invented technologies will be needed
- Moore's Law is the iconic driver of electronics progress – but it will continue until physics gets in the way (cooling!)
- Research and development is needed as never before
- Note: what follows is computer-centric, but…

Perspective on microelectronic heat flux



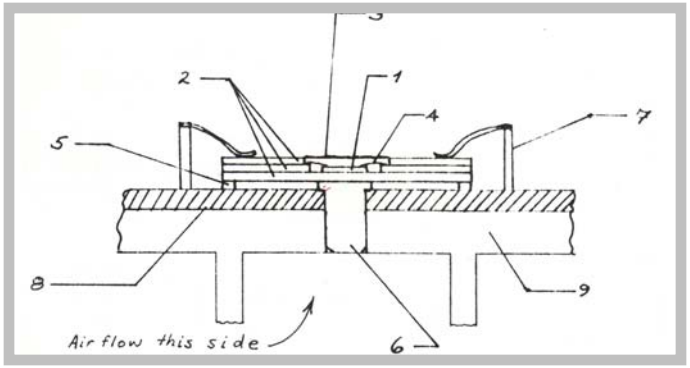
Hannemann, Bar-Cohen, and Oktay, ca. 1986

Technology generations

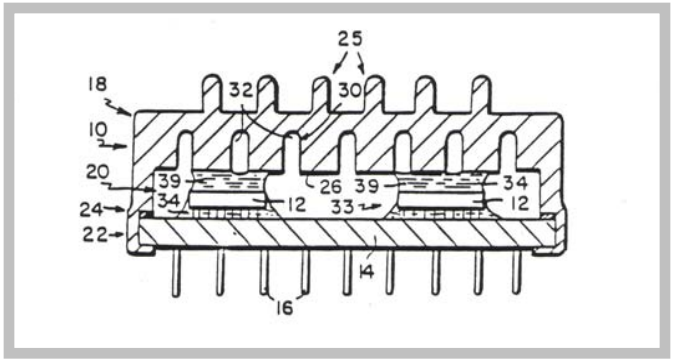
Timeframe	Generation	Representative Product	Chip Power	Module Power Density	Rack Power
1945-1955	Historic	Specialty Computers			
1955 - 1965	Transistor	Early Mainframe			
1965 - 1975	SSI	Mainframe			
1975 - 1985	MSI	Minicomputer			
1985 - 1990	LSI	Microcomputer			
1990 - 2000	VLSI	PC, Notebook, Portables			
2000 -	ULSI	Micro-based Server			

Trouble ***Design care*** ***Ignore***

What's old is new again…

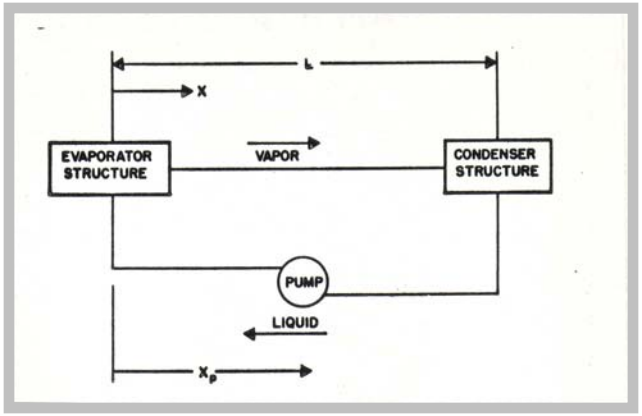


Heroic measures to maintain air cooling…

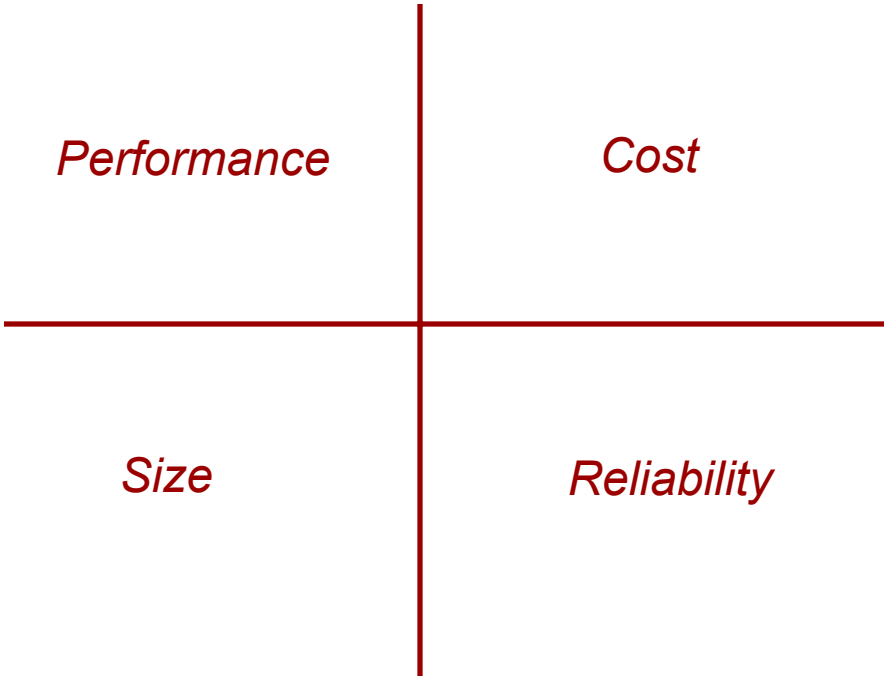


Heat pipe concepts…

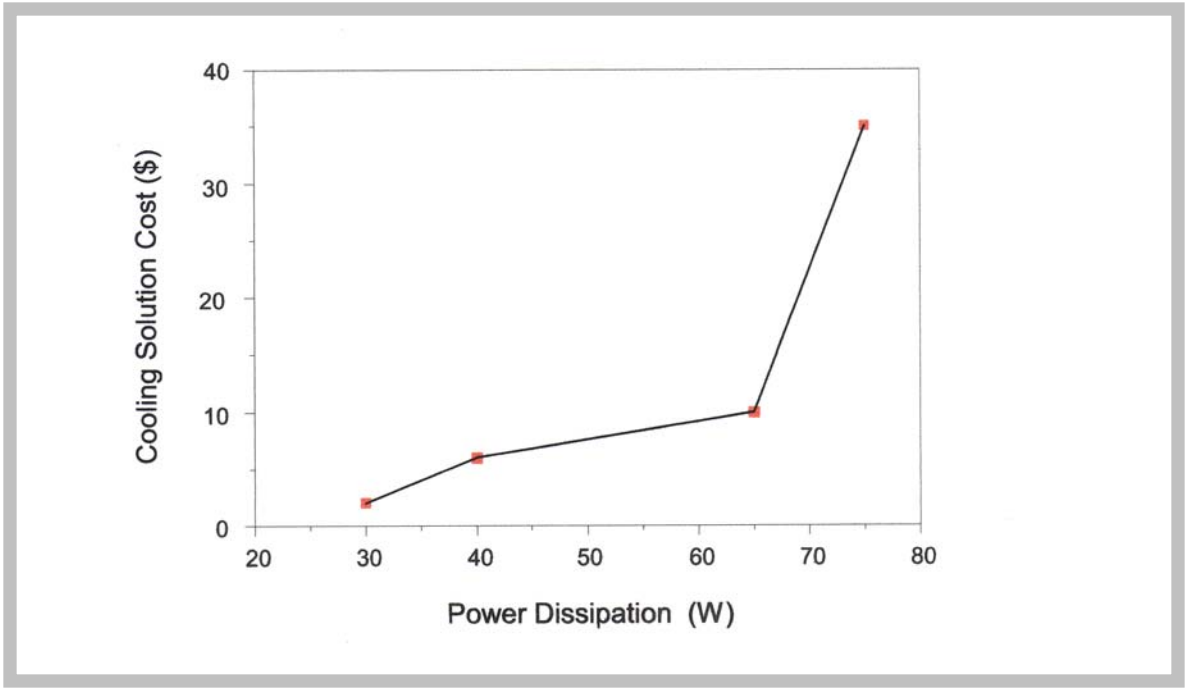
Two-phase system cooling…



Design / technology drivers

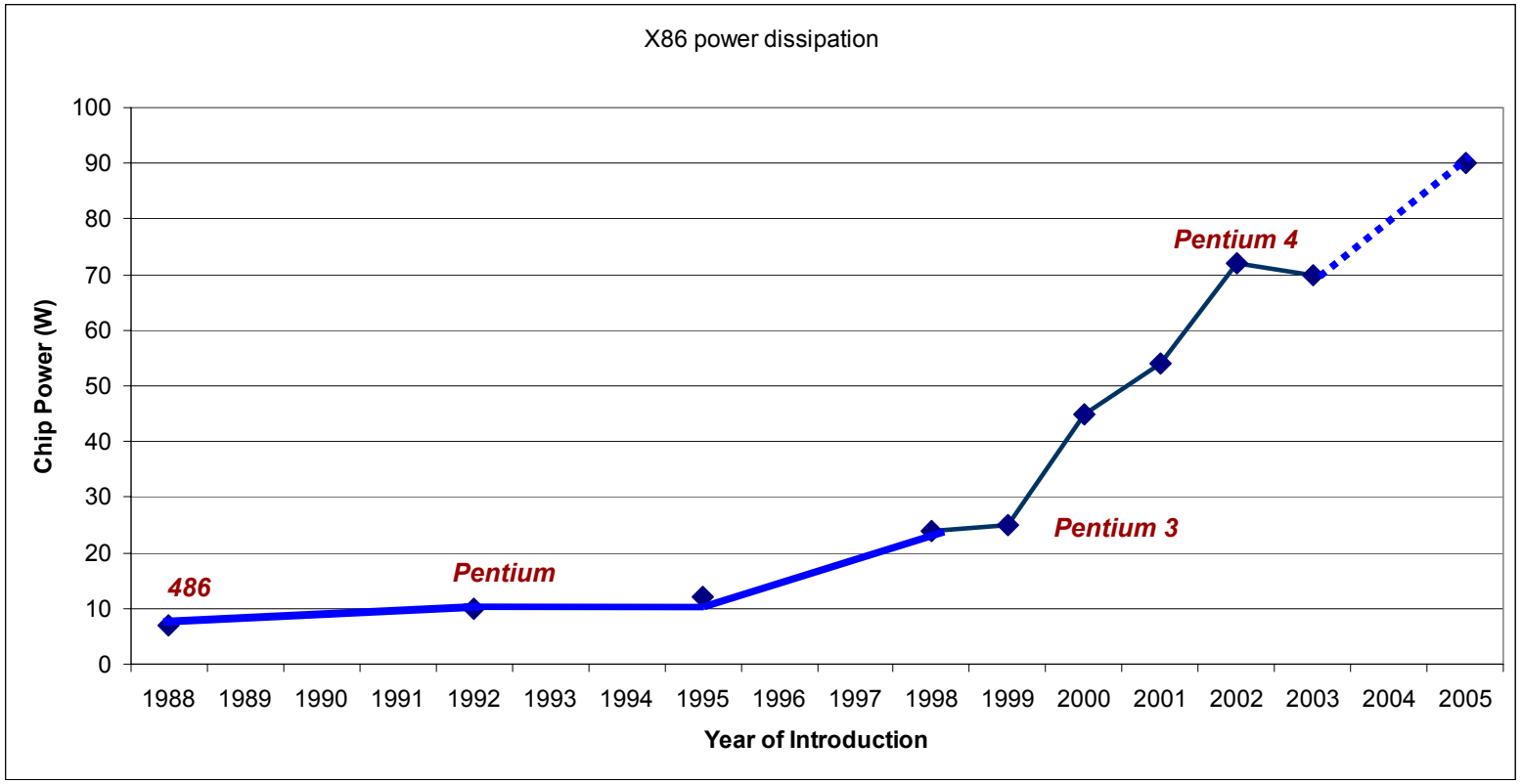


Cost of cooling

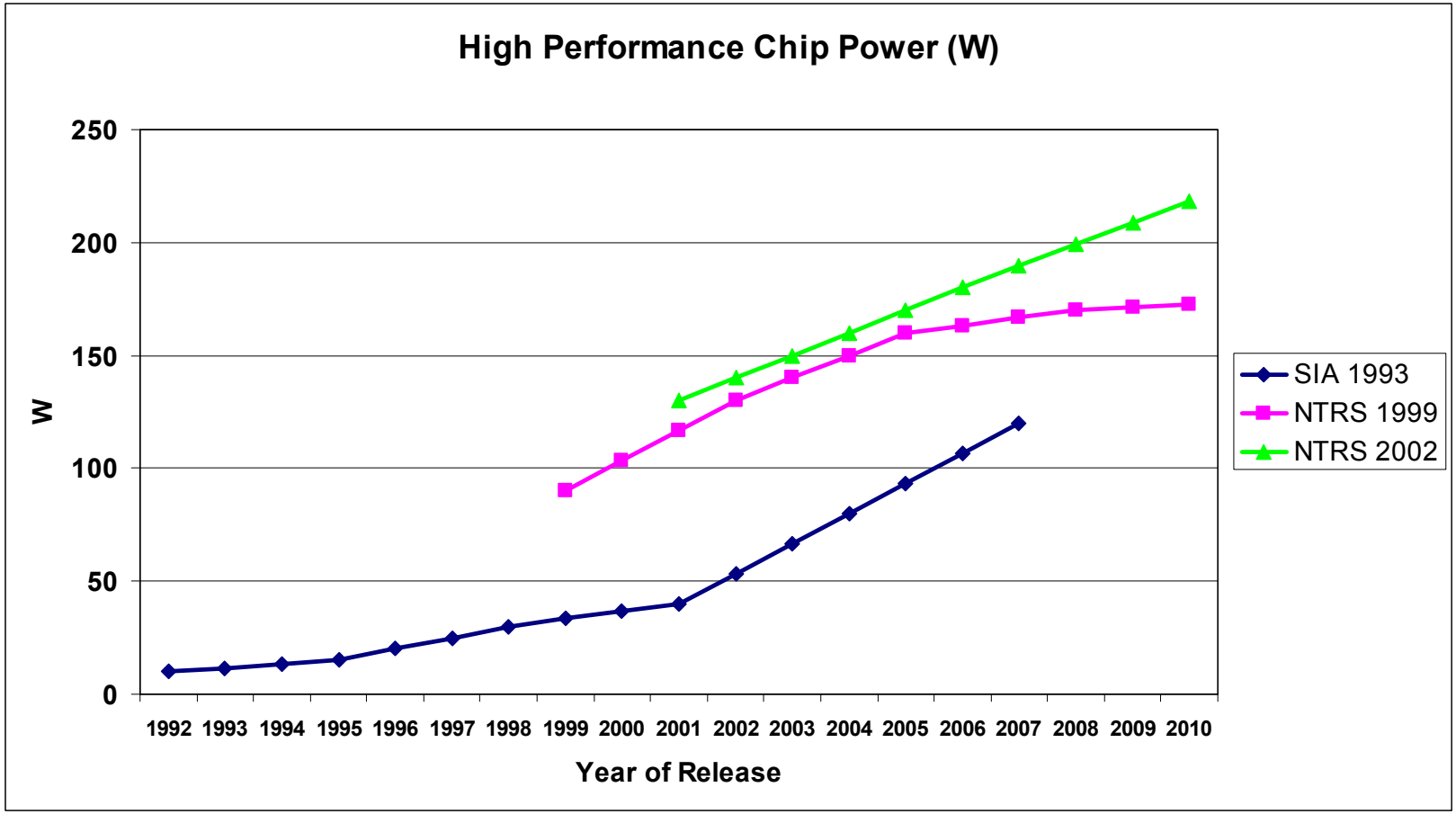


Cost of cooling a microprocessor, Intel

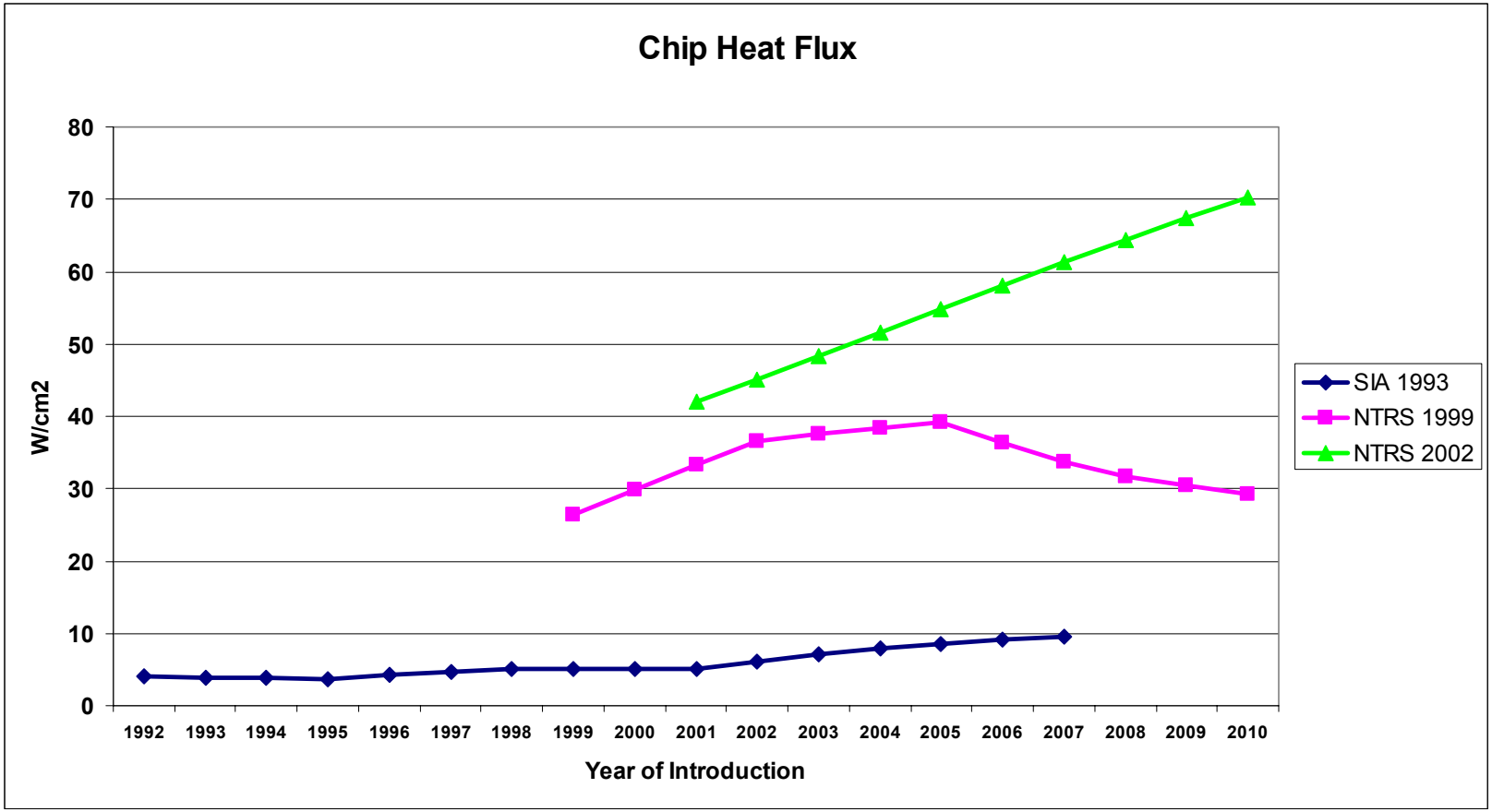
Intel's inflection



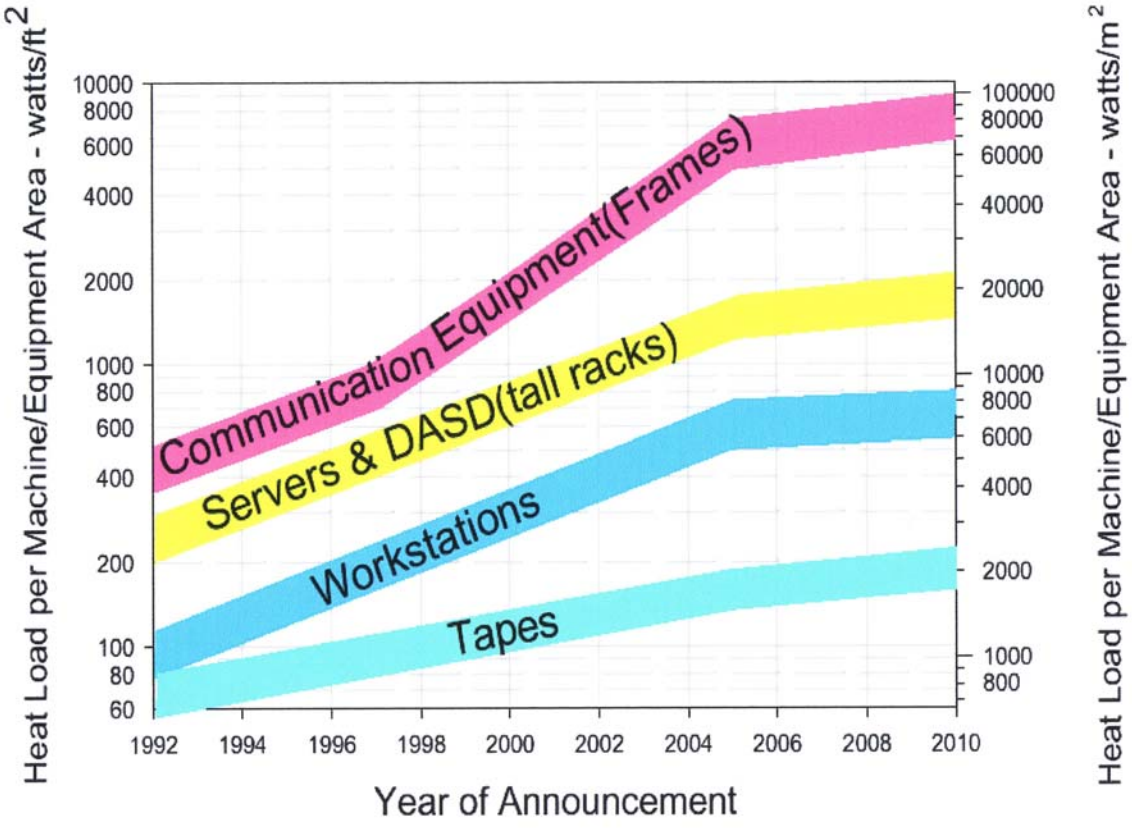
Chip power trends



Heat flux trends at chip level



A new problem: machine-room heat density



Data from Amdahl, Compaq, Dell, HP, IBM, SGI, Sun, Unisys, Lucent, Nortel, and Cisco

Key challenges: large systems

- Solutions for very high chip powers (100 – 200W)
- High reliability / availability
- Rack-level cooling
- Machine-room cooling
- Cost management

Key challenges: office systems

- Cost / performance microprocessors will reach 80 – 100W within 2 years
- Air cooling must be optimized
- Acoustics
- Reduced cost

Other challenges

- Telecom systems: central offices already stretching power limits
- Photonic components provide very serious cooling challenge
  - Thermal control at heat fluxes ~ 2 x 10^3 W/cm^2
  - Performance very sensitive to temperature
- Harsh environments
  - Automotive
  - Telecom
  - Military

Research areas

Materials

- Optimized fluids for liquid cooling
- Materials for package construction / thermal spreading
- Phase change materials for transient applications

Devices

- High static pressure, low acoustic noise blowers
- Micro heat pipe structures
- Two-phase cooling approaches
- MEMS components for liquid / two phase cooling

Design

- Small-footprint liquid cooling systems
- Package-scale jet impingement / spray cooling
- Advanced, integrated thermal design tools
- Frame and rack coolers
- Equipment room thermal design

Conclusion

- The importance of thermal management in electronics devices and systems has waxed and waned over the past 50 years
- Current technologies and applications are once again providing a serious challenge – perhaps show-stopping – to heat transfer engineers
- Breakthroughs are needed in advanced cooling technologies (and pragmatic design!) at all levels